CAPEDM : COMPUTER AIDED PROCESS PLANNER FOR ELECTRO DISCHARGE MACHINING PROCESS

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CERTIFICATE

This is certify that the present work on "CAPEDM : A COMPUTER AIDED PROCESS PLANNER FOR ELECTRO DISCHARGE MACHINING PROCESS", by AVADHESH BAHADUR, has been carried out under our supervision and has not been submitted elsewhere for award of a degree.

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ABSTRACT

In the present work, a generative process planning syste
for electric discharge machining process is designed, developed an
implemented. The system encompasses various process planning function
viz. feature combining, feature sequencing, electrode material selec
tion, machine tool selection, dielectric selection and determination o
process parameters. The system is menu driven and prvides adequat
interactiveness with the user.

The system is implemented on IBM compatible PC-XT/AT usin
TURBO PASCAL Ver. 5.0.

Dedicated

to

MY PARENTS

ACKNOWLEDGEMENT

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AVADHESH

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CHAPTER I

INTRODUCTION

There has been a rapid growth in the development of harder and difficult-to-machine metals and alloys during the last two decades. Conventional edged-tool machining is uneconomical for such materials and the degree of surface finish and the attainable accuracy are also poor. The newer machining processes developed to process such materials are called 'Unconventional Machining Processes'. As a group they are characterized by an insensitivity to the hardness of the workpiece material and hence, are suitable for shaping parts even from fully heat-treated materials, avoiding the problems of distortion and dimensional changes that often accompany heat-treetment. These modern machining methods are classified according to the type of fundamental machining energy employed, namely, mechanical, electrochemical, chemical or thermoelectric.

In thermoelectric processes, thermal energy is employed to melt and vaporize tiny bits of workpiece material by concentrating the heat energy on a small area of workpiece. These methods include Electric Discharge Machining (EDM), Laser Beam Machining (LBM), Plasma Arc Machining (PAM) and Ion Beam Machining (IBM), to name a few.

The present work is concerned with EDM. A brief introduction to EDM process is presented in the next section.

1.1 ELECTRIC DISCHARGE MACHINING

Electric Discharge Machining (EDM), also refered to as 'Spark Machining', is a method of removing metal by a series of rapidly recurring electrical discharges between an electrode (the cutting tool) and the workpiece in the presence of a liquid dielectric fluid usually hydrocarbon. Minute particles of metal or "chips" are removed by melting and vaporization, and are flushed from the gap between the tool and the workpiece. The workpiece which constitutes one of the electrodes between which the sparks occur, must be made of electrically conductive material. The other electrode (tool), which also must be made of electrically conductive material, is located in close proximity and it should never be in contact with the workpiece during cutting.

An EDM machine is needed to hold and locate the tool in a proper mechanical relationship with respect to the workpiece. It incorporates a means for relative motion between the tool and the workpiece to maintain the desired gap, which is the space between the tool and the workpiece. Modern machines provide for automatic maintenance of the preselected gap by servo control, which acts as a power feed.

EDM usually requires the presence of a liquid in the arc gap. The principal functions of this liquid are, to provide a path for the discharge of electrical currents, to remove the metal particles produced from the gap and to cool

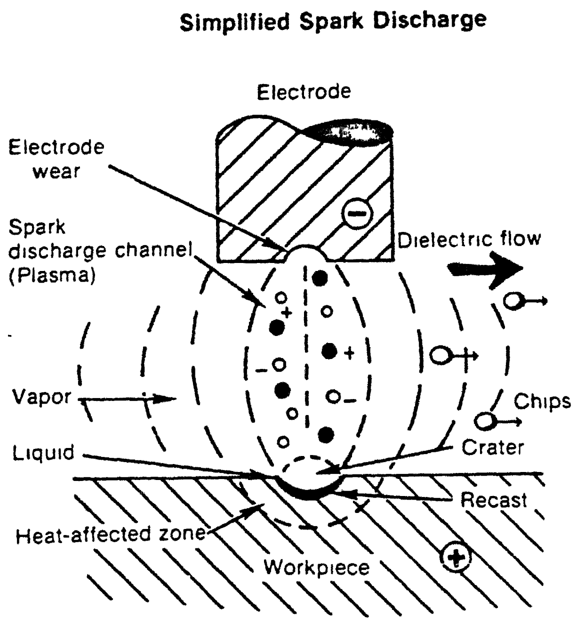
the tool and the workpiece. These functions are most easily achieved by forcing the liquid through the gap, thus requiring a pump. EDM is generally carried out with the gap well submerged in a dielectric tank. A spark generating apparatus, i.e. the power supply, is connected to the tool and the workpiece. Generally Pulse and Capacitor (RC) - type of power supplies are used. Fig. 1.1 shows the EDM parameter terminology [10].

The present work is concerned with the planning of EDM process. Certain fundamental concepts of process planning are excerpted in the next section.

1.2 PROCESS PLANNING

Alternatives to traditional approaches to design, manufacturing and management coupled with need for improved efficiency have led to the concept of integrated manufacturing systems. These employ a system of real time computer control. The importance of Computer Aided Process Planning (CAPP), as the vital link between CAD/CAM, is utmost since it provides integration leading to the ultimate Computer Integrated Manufacturing System (CIMS).

A good planning needs availability of sufficient data and their efficient handling and manipulation. In this regard computer plays a very useful role. This has become possible recently due to availability of inexpensive and powerful computing and database management system [12].



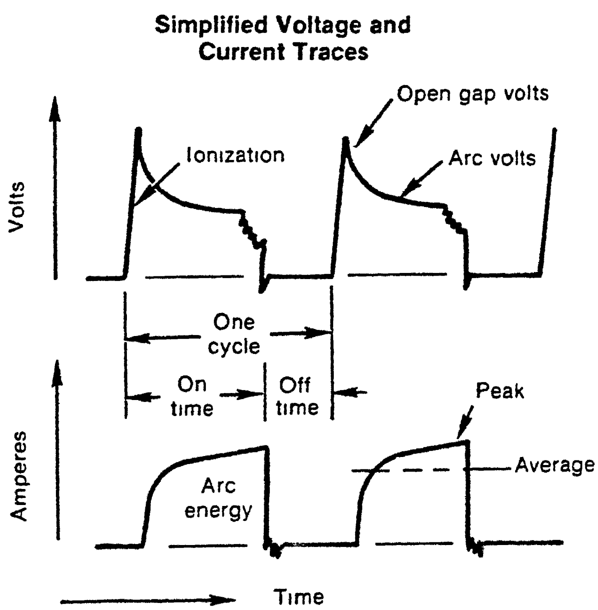


Fig. 1.1 : EDM Parameter Terminology

The process planning has been defined as the subsystem responsible for conversion of design data to work instruction. It is exclusively concerned with the selection of suitable processes and tools to transform the raw material into finished product according to its drawing. Process planning can be itemized as follows [13]:

1. Interpretation of product design data.
2. Selection of machining processes.
3. Selection of machine tools.
4. Determination of fixtures and datum surfaces.
5. Sequencing of the operation.
6. Selection of inspection devices.
7. Determination of production tolerances.
8. Determination of proper cutting conditions.
9. Calculation of overall time required for machining.
10. Generation of process sheets.

APPROACHES OF CAPP

Various approaches to computer aided process planning are [1]:

1. Variant Approach
2. Generative Approach
3. Semi-Generative Approach

VARIANT APPROACH

The variant approach to the process planning is comparable with the traditional manual approach where a process plan for a new part is created by recalling, identifying, and retrieving an existing plan for a similar part, and making necessary modifications for the new part. In this system the parts are grouped into a number of part families, characterized by similarities in manufacturing methods and thus related to group technology. For each part family a standard process plan, which includes all possible operations for the family is stored in the system. Through classifiction and coding, a code is built up, these codes are often used to identify the part family and the associated standard plan. The standard plan is retrieved and edited for the new part.

The disadvantage of this approach is that the quality of process plan depends upon the knowledge background of process planner. But, this is still popular due to lesser investment, shorter development time, lower hardware and development costs.

GENERATIVE APPROACH

In the generative approach the process plans are generated by means of decision logic, formulae and geometry based data to perform uniquely the many processing decisions for converting a part from raw material to the finished state. The rules of manufacturing and equipment capabilities are

stored in a computer system. When using the system, a specific process plan for a specific part can be generated without any involvement of human process planner. For this system input can either come as text input (i.e. interactive input), or as graphic input where the part data is gathered from a CAD module (i.e. interface input).

The process plan generated by this approach are consistent and fully automated but the initial investment is high.

SEMI-GENERATIVE APPROACH

The term Semi-Generative Approach may be defined as a combination of generative and variant approach. Here pre-process plan is developed and modified before the plan is utilized in a real production environment. This approach is an interim approach and it is still in its infancy. The decision logic, formulae and technological algorithm as well as geometry based coding scheme for translating physical features are built into the system. At the first sight, the system working steps are the same as generative approach, but the final process plan has to be examined and errors corrected if it does not fit the real production environment. The modification in the process plan is small as compared to variant approach.

The main advantages of this approach are speedy automatic production, reduced process planner's participation and it also ensures quality of the process plan.

1.3 PROCESS PLANNING IN ELECTRIC DISCHARGE MACHINING

A trouble free, continuous operation of EDM facility involves the co-ordination of the many facets of the process. Every successful implementation involves a complete team effort. A team generally comprises of people with expetise in tool design, electrical aspects, machine tool maintenance, production planning and facility engineering. Generally training is a difficult task, since few experts are available, learning by experience is long and expensive. This generally deters the user from venturing into new product areas. Any manufacturing concern installing an EDM facility needs to receive guidance in the selection of components for EDM and subsequent production. Process parameters for selected parts are supplied by the machine tool manufacturer's R & D.

The basic principal of tooling design and operation are not directly available to users. For most of the people it still remains an art rather than technology. Process parameters are a result of large scale experimentation.

Cornelission, Snoeys and Kruth [2] conducted a number of experiments for comparing EDM systems with Pulse-type of power supply. They have plotted various machining parameter on multi-axial space diagram. These diagrams can be used for selecting machining parameters. However this approach can not be generalized due to pulse-type of power supply and inconsistent results.

Crookal and Cranfield [3] have given the EDM parameters for few cases of forging dies, plastic molds, casting dies and extrusion dies. But again this approach can not be generalized.

1.4 SCOPE OF PRESENT WORK

From the above discussed literature, it is evident that a logical approach to process planning in electric discharge machining does not exist. Experience in this field has become extremely important and it does not have an efficient substitute. This it seems is major obstacle in the acceptance of this process by manufacturing concern.

Process planners heavily rely on the empirical relationships as well as on the experimental data for the development of process plans. As a first step towards the automation in EDM process planning, the present work attempts to develop a systematic methodology for generation of computerized process plans.

A fully interactive program that ensures that the experience of the planner is not missed at any stage has been developed and coded in Turbo Pascal version (5.0). It is divided into two modules. The input module takes the information about the raw material, features to be machined and available machine tools. The planning module combines the features in a logical fashion to achieve economics of tooling and machine tool capability. The selected areas are sequenced for machining and operating parameters are determined.

The application of proposed methodology will significantly reduce the time, efforts and costs involved in development of the process plans for EDM. The intention of the present system is to systematize the process planning procedure for EDM based on logical theory and practice. This package utilize the experimental data [4,10] and empirical relationships for the development of the process plans. The procedure as such guides the process planner through various facets of the process planning. Therefore, it aids to partially substitute the lack of experience and training on the part of the process planner.

1.5 ORGANIZATION OF THESIS

Chapter II deals with the design and development of proposed CAPP system. A description of the system is presented at the beginning of the chapter. Each step is then extensively discussed in separate sections.

Chapter III gives the implementation aspects of the system. Here the programmed procedures, their operation and end result have been elaborated upon.

In Chapter IV complete process plan for the test component have been presented. The procedure adopted in reaching the final plan has also been discussed.

In Chapter V conclusions and suggestions for further improvement over the present system are presented.

CHAPTER II

SYSTEM ANALYSIS AND DESIGN

Electric Discharge Machining is generally associated with the machining of high-strength, temperature resistant alloys and hard-to-machine conductive materials. A process planning system has been developed with the objective of improving effectiveness of the process. In this chapter a general description of the process planning system is presented. Based on these concepts, an interactive system for components machined on standard sinking machines has been developed and implemented. The details of the implementation are presented in the next chapter.

2.1 SYSTEM DESCRIPTION

Fig. 2.1 gives the overall structure of the system. It can roughly be divided into two modules :

(i) Input Module

(ii) Planning Module

The planning module receives the relevant data/information from the input module. The modules are described in the following sections.

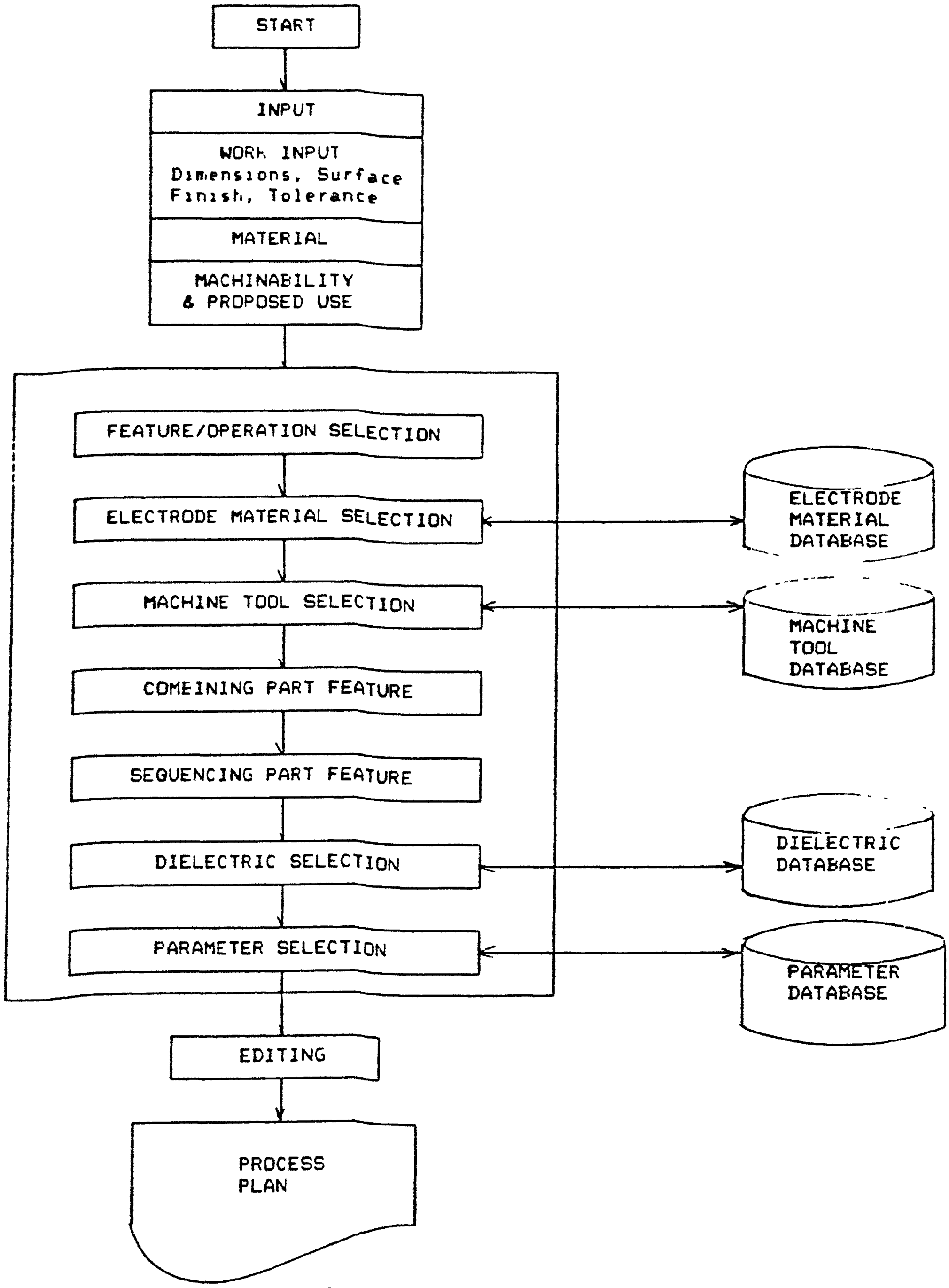


Fig. 2.1 : Process Planning Modules and Database for EDM

2.2 INPUT MODULE

All the relevant data to plan machining is collected in this module. The necessary input information are blank dimensions, finished part dimensions, shape, surface finish, material and the machinability requirement. Blank dimensions are used during the stage of the preliminary selection of the machine tool. The shape of finished product determines the various features to be machined.

Normally, surface finish which can be achieved in EDM lies between 0.2 - 6.3 µm R_a [10]. The size of craters produced in the workpiece surfaces by electric sparks depends upon the energy of discharge. The discharge energy is determined by the gap voltage during discharge, the discharge current and the length of time the current flows. There is a need to control the above parameters when particular surface finish is desired.

Machinability requirement is of paramount importance in electric discharge machining. Machinability refers to the ease of metal removal. Generally it is classified as good, fair and poor. A material is said to have good machinability if it can be machined with less tool wear. For example the machinability of Aluminum is Good while that of Tungsten is poor.

In EDM operation the normal range of tolerance is ± 0.025 mm, however with careful selection of parameters the tolerance in the range of ± 0.005 mm can be achieved [10].

2.3 PLANNING MODULE

The planning module has a hierarchical structure. It first selects the electrode material and machine suitable for the component. In EDM, a number of geometrical feature of the part can be combined and machined using a single machine tool. Advantage is taken of this fact and machining areas are selected by combining features in the workpiece. After this the operations are sequenced and various process parameters such as current, voltage, metal removal rate (mrr) etc. are determined. The various steps in the module are described in subsequent subsections.

2.3.1 ELECTRODE MATERIAL SELECTION

The EDM tool electrode is the means by which the current is transferred to the workpiece. A requirement for any electrode used as EDM electrode is that it should be electrically conductive. A large number of materials are used as electrodes in EDM. The most commonly used materials are Graphite and Copper. There is a need to create a database for electrode materials. The selection of electrode material is done based on workpiece properties, machinability requirement, proposed use and relative workpiece to tool wear. In most of cases it is difficult to narrow down the selection of electrode material to a single electrode material, for a particular workpiece material, and more than one electrode materials are available. In these cases final selection is based on practical aspects.

Polarity of workpiece also plays a very dominant role in EDM. Positive polarity means that positive end of supply will be connected to workpiece and negative to tool electrode. This can be used either in Capacitance (RC)-type power supply or Pulse-type power supply. Negative polarity is just reverse of previous one and is also known as **No-Wear EDM.** While machining with negative polarity of workpiece the tool wear of less than one percent is achieved. But, the major constraint with it is that it can be used only when Pulse-type of power supply is available.

2.3.2 MACHINE TOOL SELECTION

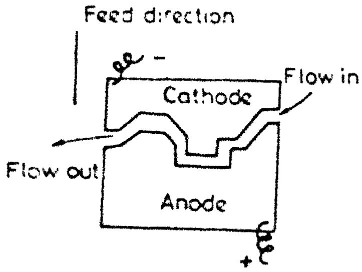
The various specification of machine tool which should be considered are maximum current permissible, maximum voltage, minimum voltage, maximum machinable area, clamping plate dimensions, type of power supply, dielectric flow rate and viscosity. The higher the maximum permissible current on the machine tool the greater will be the mrr. The dielectric flow rate influences the flushing, while the dielectric velocity increases the tool wear. There is a need to create a database for machine tools. A facility should be provided to edit and append the database.

2.3.3 WORKPIECE FEATURE/OPERATION DESCRIPTION

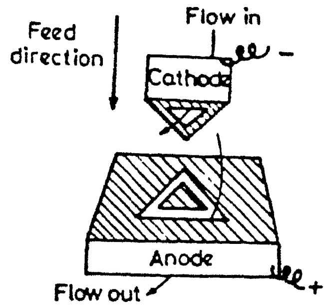
Machining of any complicated shape component by a single tool electrode is avoided since it requires first to machine the tool electrode to corresponding shape which is difficult and uneconomical. Also the maximum permissible machining area on the machine tool may not permit the same. So the component shape is decomposed into geometrical shapes i.e. circular, square, triangular, arc, hexagonal and the available standard tools of the above shapes are used.

Operation selection is done for each feature for which the machining is to be performed. The various possible operations on EDM are : drilling, trepanned shape machining, external shape machining, die sinking, internal grooving, counter boring, counter sinking. These operations are illustrated in the Fig. 2.2.

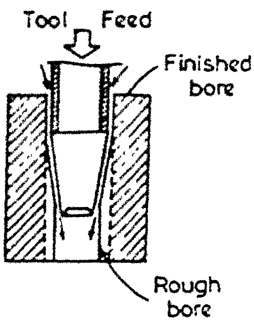
Two principal EDM operation i.e. roughing and finishing are considered. Bulk of material removal is the only consideration in the roughing operation and no consideration is given to the surface finish and tolerance of the machined surface. When performing the EDM roughing cuts at higher amperage, a recast layer is developed on the machined surface [10]. Thus, the finishing operation should be performed in such a manner that it removes the recast layer and brings the dimensions within the tolerance limit.



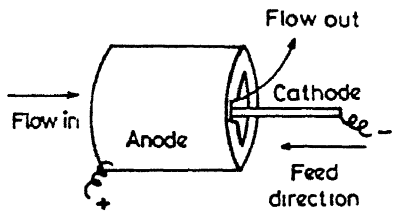
Die Sinking



Trepanning



Counter Boring



Internal Grooving

Fig. 2.2 : EDM Operations

2.3.4 COMBINING OF FEATURES

Electric Discharge Machining of components may comprise a single operation or a number of operations, each producing some selected feature area in the component. The latter procedure is adopted to give better tooling arrangement and economical machining. However, selection of these areas depends entirely on the geometrical characteristics (shape and size), machine tool capacity, surface finish requirements. Data/Information from the previous modules are used in an effective manner to obtain logical combination of operations. The following combinations in their order of appearance represent a logical set.

1. Combining embedded feature
2. Combining features using natural point for dielectric entry
3. Combining similar features
4. Combining remaining features utilizing machine tool capacity.

The process of selecting features for combinations is illustrated with a flow chart in Fig. 2.3 , as indicated in the figure the combined areas should have the same type of operation finish i.e. either rough or finish and common direction of tool movement. Further the feasibility of tool design is decided considering practical aspects. If the area to be machined exceeds the maximum permissible area for the machine tool, splitting of the area is carried out as shown in Fig. 2.4, based on maximum permissible area of the machine

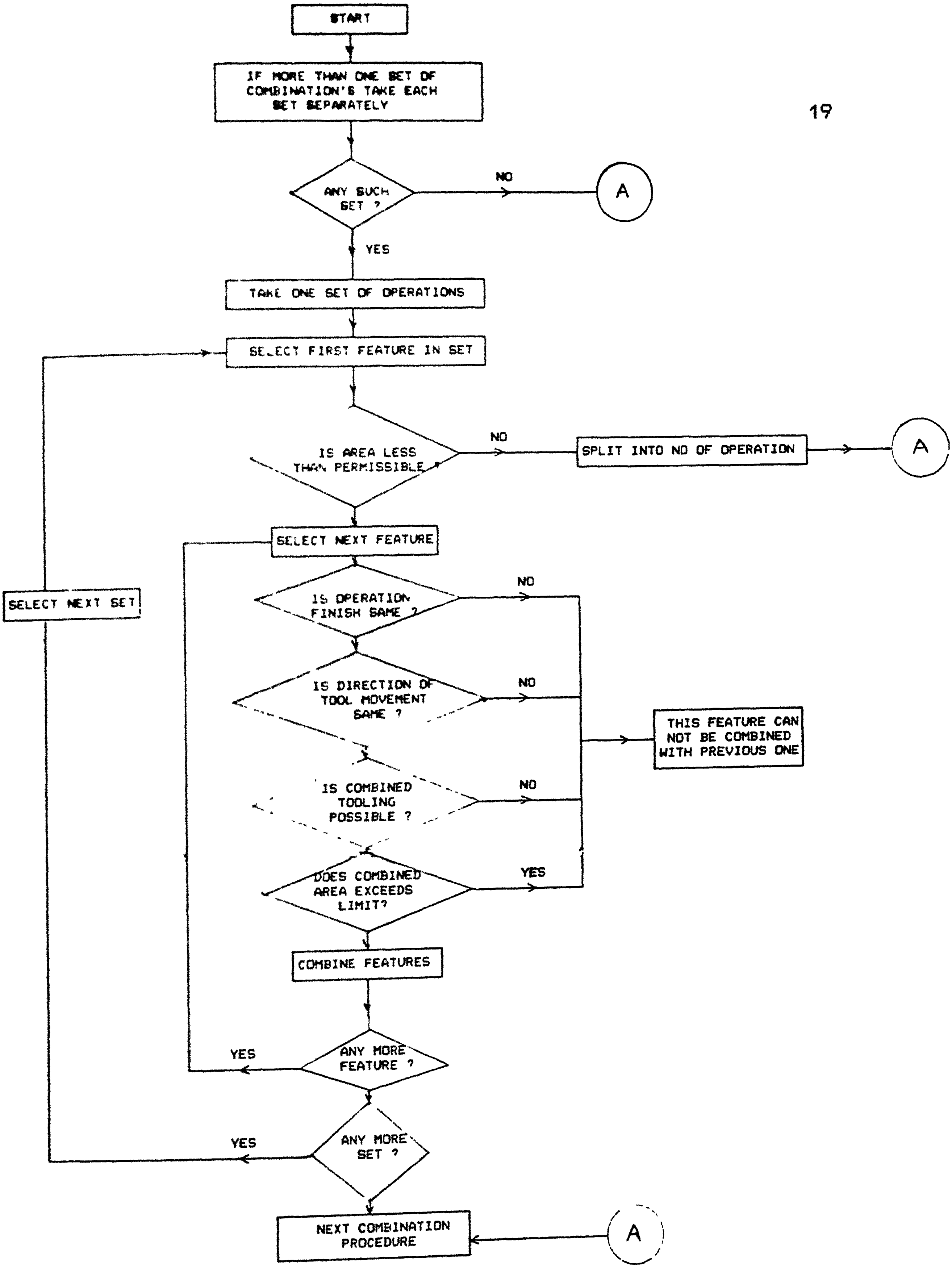


Fig. 2.3 : Flow Chart for Combining Features

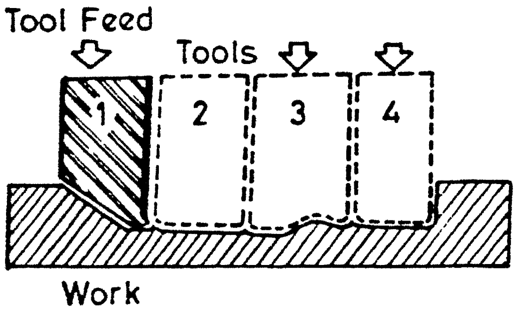


Fig. 2.4 : Splitting of Large Area

tool i.e. that particular feature will be machined in more than one stage. Features that are not combined with each other are also checked for maximum permissible area and if needed these areas are also split into sections.

2.3.5 SEQUENCING OF OPERATIONS

To sequence a number of electric discharge machining options on a component several factors need to be considered. These are technological, dimensional, geometrical constraints and dielectric flow arrangement constraints.

Technological constraint is evaluated on the preceding operation to be performed. Drilling of a hole might require two successive operations ; a rough stock removal and then bore sizing. Thus, for the operation bore sizing, a rough stock removal stage is a technological constraint.

In case the location of a particular surface (i.e. center of bores) depends on machined surface, then the machining of latter surface is a dimensional constraint on the hole producing operation.

Geometric tolerances i.e. parallelism, angularity etc., are specified for a particular surface from a reference surface. If this reference surface is also to be machined, then it may automatically become a geometrical constraint for any other surface referenced from it. Thus, this reference workpiece shown in Fig. 2.5, whose surfaces are to be

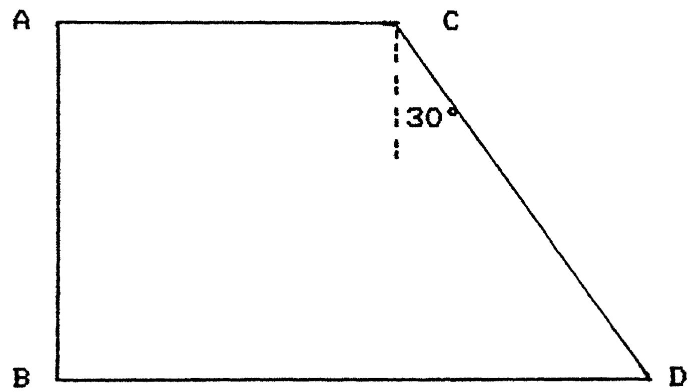


Fig. 2.5 : Geometrical constraint for machining

machined by EDM. The angularity of the surface CD is referenced from AB. Therefore, AB has to be machined first and it become a geometrical constraint on CD.

Dielectric flow arrangement constraint occurs when dielectric is exhausting through previously machined surface. Chips produced during machining are also exhausted with dielectric fluid, since the chips are electrically conductive they may cause the spark between finished surface and tool electrode and erosion of material occur. This is undesirable, so features to be machined are selected in such a manner that above situation is avoided.

2.3.6 DIELECTRIC SELECTION

Principal function of the dielectric fluid in the EDM are :

(i) It insulates tool electrode and work until required conditions are achieved.

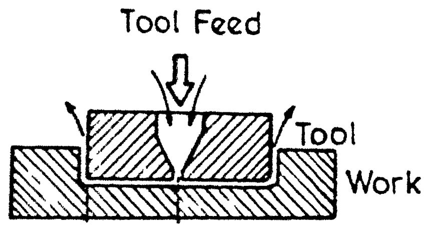
(ii) It flushes eroded particles out of the spark gap.

(iii) It cools the tool and the workpiece.

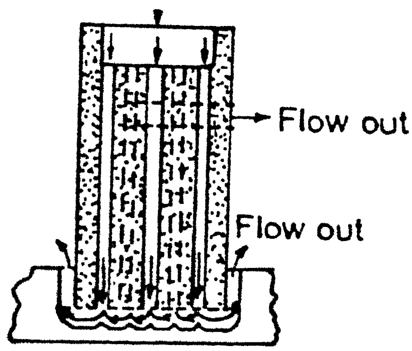
There are a number of dielectric fluids used in EDM. The most commonly used fluid is Kerosene. The various dielectric properties which are needed are viscosity, flash point temperature, thermal conductivity, boiling point etc. So for making suitable selection combining these characteristics, there is a need to create a database for dielectrics.

The preliminary selection of the dielectric fluid is made on the viscosity consideration. Fig. A.2 shows the relationship between viscosity and surface finish. Based on the surface finish requirements the minimum and the maximum viscosities are calculated and the dielectrics falling in this limits are selected. Discharge of spark causes erosion of material from the tool and the workpiece and simultaneously it also increases the temperature of the dielectric fluid in contact. The final selection of the dielectric is made, based on maximum temperature which it can sustain and it should be less than flash point temperature of the dielectric. At this point if more than one dielectric fluid are selected, the final selection is based on practical consideration.

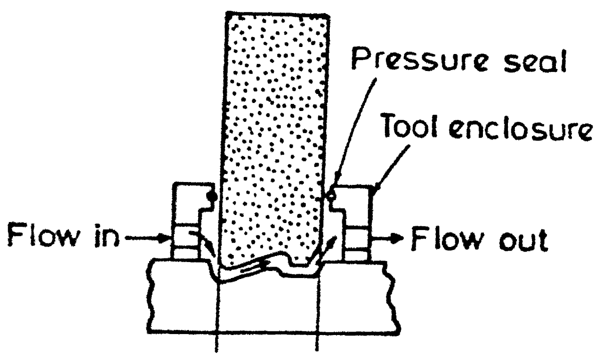
Flushing is the most important requirement of dielectric fluid. Inadequate flushing can result in arcing, decreased electrode life and increased production time. There are several method to introduce the dielectric fluid to the arc gap i.e. normal flow, jet flushing, immersion flushing, vibratory flushing [4]. Flushing of the inter electrode gap can be achieved either by pressure flushing or vacuum flushing. Vacuum flushing is generally recommended for finishing operation, however final selection is made considering practical aspects. Various dielectric flow arrangements are shown in the Fig. 2.7.



Straight/Forward



Reverse



Cross

Fig. 2.7 : Dielectric Flow Arrangements

Wells and Willey conducted a number of experiments on EDM and found that for a wide range of machining conditions following values approximately remain constant [14].

Optimal Dielectric Discharge (Q_{opt}) = 1.3 lt/sec

Optimal Dielectric Velocity (V_{opt}) = 6 m/sec

Optimal Dielectric Pressure (P_{opt}) = 1 atm

2.3.7 PARAMETER SELECTION

An important function of the process planning is to provide the details of various process parameters such as voltage, gap, current, mrr, capacitance, arc duration, frequency etc. for each operation as these factors affects the cost and quality of the product. To do this job manually is to look into the data books for each minor operations, select the parameters based upon individual experience or obtain these from empirical relations (again taking help of data book). This ultimately leads to wastage of time and sometimes inconsistency in the selection. To overcome these problems there is a need to create a database for EDM parameters. Such a database would enable a quick retrieval and would have no data inconsistency. Some parameters can be computed using empirical relationships represented by graphs.

CHAPTER III

SYSTEM IMPLEMENTATION

The process planning system designed and developed as explained in the previous chapter is implemented on PCXT/AT operating on MS-DOS version 3.3 and coded in Turbo Pascal version 5.0. The Turbo Pascal version 5.0 has well organized data structure facility and the need for additional database language is eliminated. Its modular programming facility (particularly creating units) has immensely helped in managing all the files written in it to create a stand-alone executable program. The system is designed to be interactive and user friendly and receives inputs from the user in the menu options. The user is not required to have very detailed technical knowledge about the machining process or process planning functions. Most of the inputs required from the user pertain to the geometrical features of the parts.

The various data are managed through different kind of data structure in Turbo Pascal like arrays and records. Record type data structure is extensively used.

The total flow of data in the present software is given in Fig. 2.1. In subsequent sections, various aspects of implementation are described.

3.1 ASSUMPTIONS

The assumptions made during the development of the system are:

1. The work material preparations (e.g. heat treatment, etc.) have been done prior to machining in order to achieve desired surface finish and dimensional tolerance.
2. For the selected machining areas, it is possible to design the appropriate tools.
3. All the operations can be carried out on the same machine tool.
4. Material removal due to frontal spark is considered only.
5. Present system supports straight cuts only.
6. If any slot is provided in the tool electrode for the dielectric flow then its dimensions are negligible as compared to work piece dimensions.
7. Area to be machined is the plan area perpendicular to the feed direction.
8. Normal dielectric flushing arrangement is selected.

3.2 MENU STRUCTURE

The menus in the system are classified on the basis of their intended functions. The main menu lists various options most of which again lead to sub-menus and sub-sub-menus. Fig. 3.1 shows the menu structure and the various sub-menus and associated individual options embedded in the present software. The hybrid of hierarchical and chain

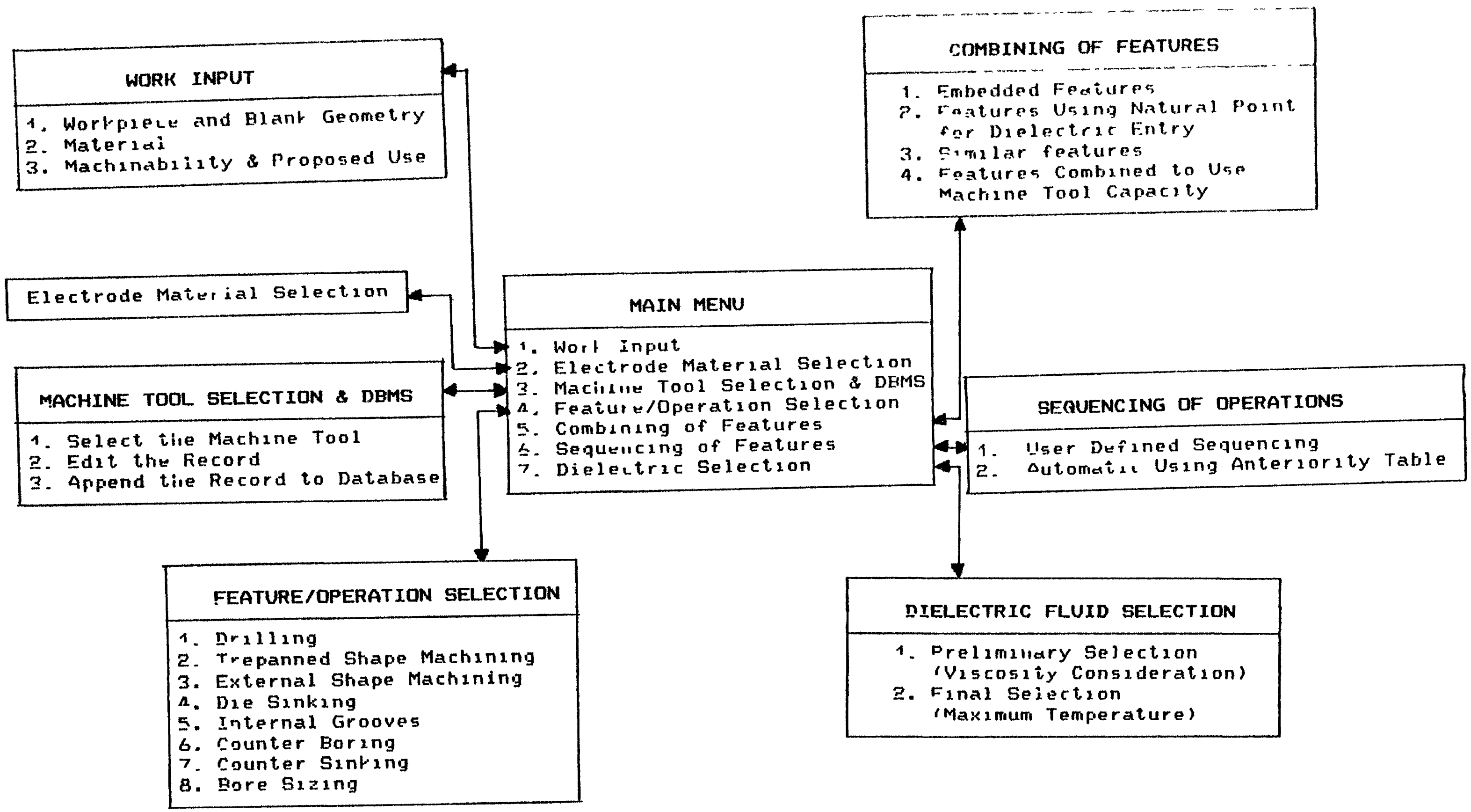


Fig. 3.1 : Menu Structure

menu structure can be easily traversed by entering the corresponding number at appropriate place.

3.2.1 WORK INPUT MODULE

The detailed analysis and design related to this module are presented in section 2.2. The various options in it are self explanatory.

(1) Data from the drawing sheet is entered by the user in this module.

(2) The material of the workpiece is selected from the list available. The present software considers the following materials only :

Steel	Brass
Carbide	Tungsten
Copper-Tungsten	Nickel Alloy
Aluminum	Graphite
Copper	

However, they are further classified into their respective types and are given in Appendix A.

(3) Machinability requirement has been selected from the option Good, Fair and Poor. Their meanings have been explained in section 2.2.

The procedure to perform this module is INPUT and it contains nested procedures : WORKMTL, MATERIAL and MACHINABILTY.

3.2.2 ELECTRODE MATERIAL SELECTION MODULE

This module receives the input from the previous module. The inputs are processed as explained in the chapter2 (Section 2.3) and electrode material is selected. In most of the cases more than one electrode material are selected, final choice is then left for the user. The procedure to perform this module is ELECTRODE.

3.2.3 MACHINE TOOL SELECTION AND DBMS MODULE

The various options in this module are shown in Fig 3.1. Data about the machine tool is stored in the file of records. Various specification of the machine tool considered are :

Machine Tool Code number	Clamping Plate Length
Maximum Current	Clamping Plate Width
Minimum Operating Voltage	Maximum Dielectric Velocity
Maximum Operating Voltage	W/P Height Permissible
Maximum Area Machinable	Type of Power Supply

(1) Preliminary selection of machine tool is based on blank dimensions, polarity of the selected electrode material and availability of the machine tool. Machine tool for which process plan is to be obtained is selected by user.

(2) Editing of the machine tool specifications can be performed with this option.

(3) If new machine tool becomes available then its specification can be appended to database.

Procedure to perform this function is MCTOOL.

3.2.4 FEATURE/OPERATION SELECTION MODULE

In this module information relevant to features, to be machined on the work piece is entered by the planner . The geometrical shapes into which component shapes can be decomposed are Circle, Square, Rectangle, Arc and Triangle. The input here is basic dimensions and it calculates area and volume of the workpiece to be removed. If any irregular shape is encountered then user is asked to enter the area and volume of the material to be removed.

The operations which are considered in the present system are shown in Fig 3.1. These are explained in the section 2.3.3. Initially the system specifies the dielectric flow arrangement however, this can be changed at the end of the module. This module is performed by the procedure FEATURESELECT and it contains a number of other procedures.

3.2.5 FEATURE COMBINING MODULE

The various strategies for combining the features are shown in Fig 3.1 and explained in the section 2.2.4. This module checks if the features can be combined with a single machine tool. Initially the features selected are checked for maximum permissible area. If the areas are less than permissible the features checked for operation finish, tooling arrangement and direction of tool movement. If these things are same then the features are combined and their areas are

added, which is again checked for maximum permissible area. If the area exceeds than the maximum permissible area, then the number of stages into which the feature will be machined is calculated. The procedure to perform this module is COMBINE. It also calls the procedures PRINTFEATUREAREA and PRINTSELECTFEATURE.

3.2.6 SEQUENCING MODULE

There are two options in this module, in the user defined sequencing the user specifies the sequence of operations. In the automatic sequencing using anteriority table the following procedure is adopted.

1. The first step involves the preparation of a table with operation in the rows and constraints in the columns. Each cell then gives the constraining operation. We then have a table of anteriorities. This table needs the user interaction for filling and is carried out manually by planner.
2. In the second step anteriority matrix is prepared. Rows and columns represents the intended operations in the same order. An entry (y) is made if any row (operation) is constrained by a column (operation) ; all entries begin in strict accordance with the table of anteriorities.
3. Next the final sequencing of operation is established. This procedure is carried out by the computer as follows. There is always a row (operation) without any

constraints. This is the first operation to be performed on the workpiece. The row and column corresponding to this operation is deleted from the matrix. In the next iteration a search is again made for the operation without any constraints. If at any time there are more than one operations without any constraints, then, these operations are displayed on the screen and user's preference is asked.

Provision is made to check the validity of anteriority table. If the user makes any fault in entering the elements in the table then error message is displayed and the user is asked to correct it. The procedure to perform this function is SEQUENCE, however it calls the other procedure at appropriate places.

3.2.7 DIELECTRIC SELECTION MODULE

Analysis for selecting the dielectric fluid is explained in the section 2.3.6. For efficient handling of data a database for dielectric fluid is created. The dielectric is selected based on viscosity and flash point temperature. If more than one dielectric fluid are selected then the final choice is left to the user. The procedure to perform all these functions is DILECT.

3.2.8 PARAMETER SELECTION MODULE

This module selects the various process parameters

for different features to be machined on the component. The

Fig. 3.2 shows how the parameters are selected. Based on surface finish and tolerance, firstly for each feature the maximum possible mrr and current are selected. The maximum current selected is checked for maximum current permissible for the machine tool and if it is more than it then maximum current permissible on machine tool is taken for machining and correspondingly mrr and depth of recast layer is selected. Based on surface finish, tolerance and recast layer depth mrr and current for finish operation is calculated. The gap voltage, gap size, frequency, capacitance are also selected. The main procedure to perform this module is PARAMETER but it calls many other procedures also.

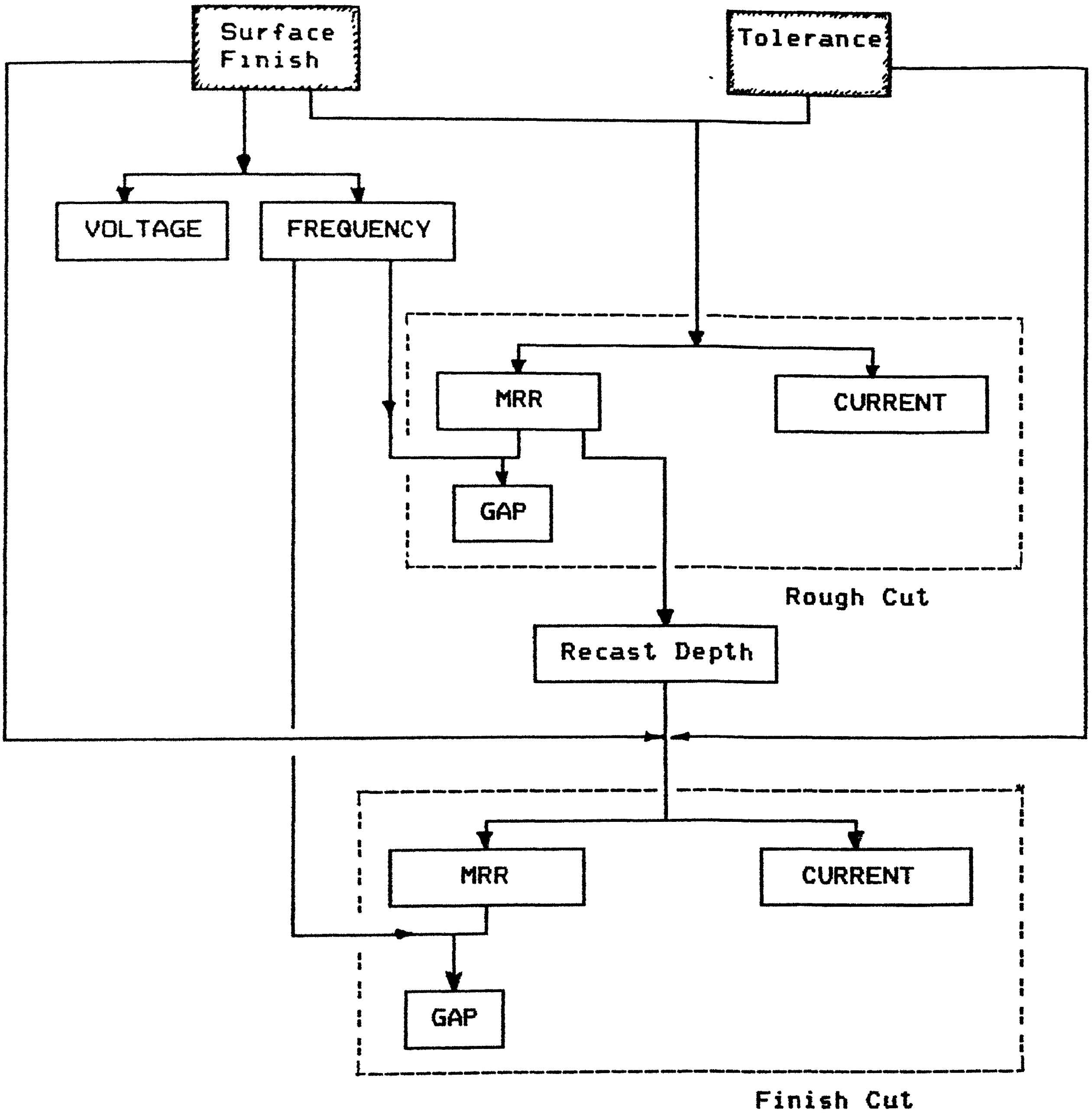


Fig.3.2 : Flow Chart for Parameter Selection

CHAPTER IV

TEST RUN AND RESULT

To test the capability of the system, test runs were conducted. Complete process plan for a component has been prepared and presented in this chapter. For a component, the raw material shape prior to machining is shown in the Fig. 4.1 by the dashed lines. It is assumed that the other finished surfaces have been produced by other methods of processing.

EXAMPLE

The following steps are to be performred to obtain the process plan :

(a) In the input module the blank dimensions, finish part dimensions, surface finish are entered and material and machinability requirement are selected. The material is Chromium Steel with surface finish requirement of 1 μm.

(b) The features to be produced are identified and shown by the numbers in the part drawing. Corresponding to each feature the operation selected is shown in Table 4.1.

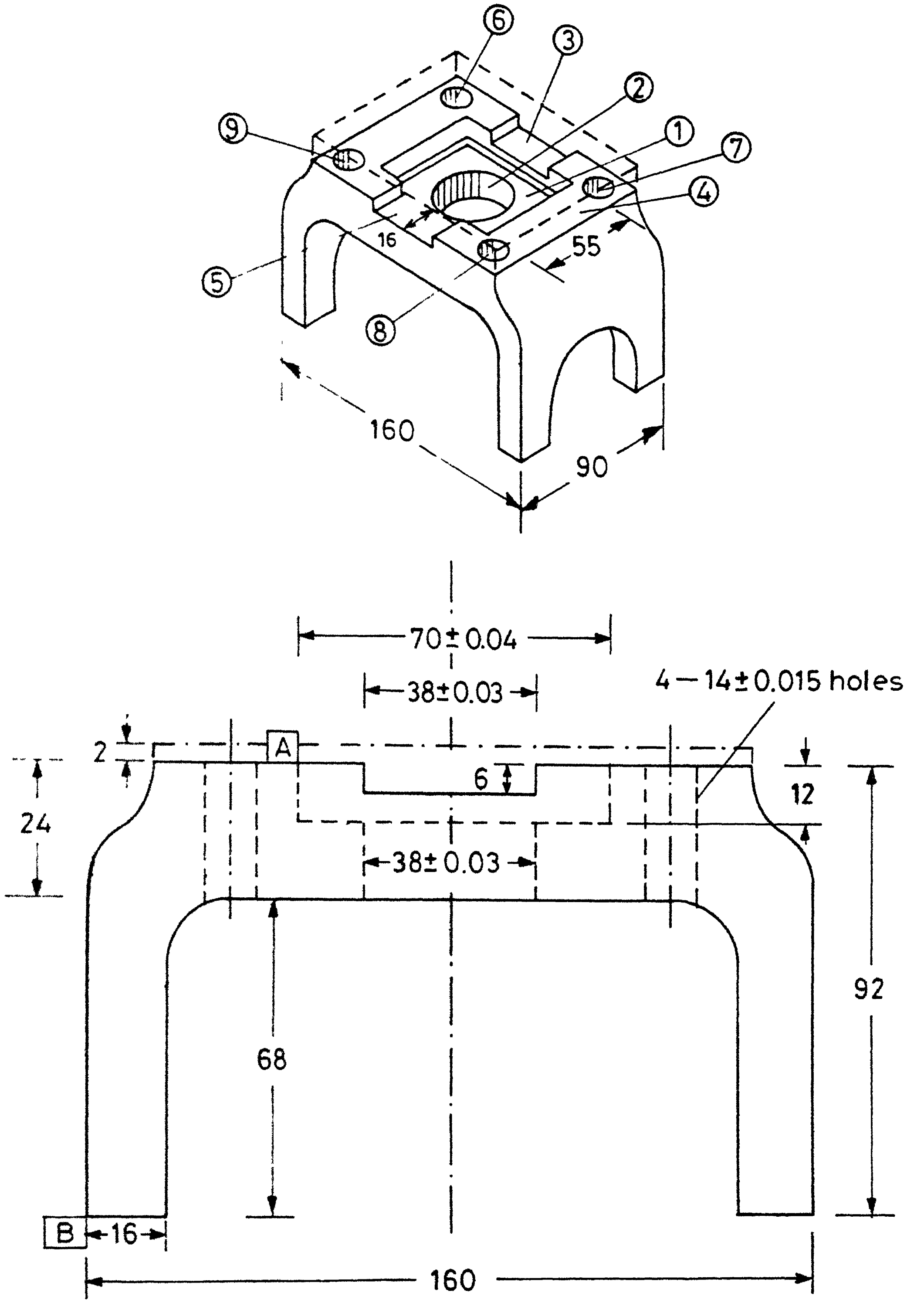
(c) In the electrode material selection module two electrode materials were found suitable in which graphite is selected for machining.

(d) The machine tools that are suitable for production run are identified from database with help of database management program . Two machine tools were found suitable for component, in which MC1 is selected for machining and its specifications are listed in Fig. 4.3.

(e) Next the features are combined for machining. The letters R and F represents rough and finish cut separately. Features (1R+2R) are combined since they have same direction of tool movement, finish, tool design feasibility. Operation (4R) was also tried to be combined with them but the maximum permissisble area on machine did not permit the same. Similarly features (1F+2F) have been combined. Features 6,7,8 and 9 are combined since they are similar features. Based on same concept operation 3 and 5 are combined.

(f) Features are then sequenced for machining. The method of anteriorty is adopted to establish correct sequence. The table of anteriority is shown in Table 4.2. It is seen that operations (4R) have no constraint so it becomes the first operation for machining. Since the location of (5R+6R+7R+8R) depends upon (1F+2F) so it becomes dimensional constraint. Similarly (1F+2F) is dimensional constraint for (3R+4R) Sequenced operation are shown in the process plan.

The final process plan is shown in the Fig. 4.2.



(Dimensions are in mm)

Fig. 4.1 Part drawing for example part.

Table 4.1 : Feature/Operation Description for the Example Part

Feature No	Operation Type	Basic Shape	Dimensions (cm)	Depth of Cut (cm)	Tolerance (mm)
1	Die Sinking	Rectangular	7 x 5.5	1.2	± 0.04
2	Drilling	Circular	3.8	1.2	± 0.03
3	Die Sinking	Rectangular	3.8 x 1.6	0.6	± 0.03
4	External Shape Machining	Rectangular	16 x 9	0.2	–
5	Die Sinking	Rectangular	3.8 x 1.6	0.6	± 0.03
6	Drilling	Circular	1.4	2.4	± 0.015
7	Drilling	Circular	1.4	2.4	± 0.015
8	Drilling	Circular	1.4	2.4	± 0.015
9	Drilling	Circular	1.4	2.4	± 0.015

Table 4.2 : Anteriority Table for the Example Part

	Technological	Dimensional	Geometric	Dielectric Flow
1R+2R	–	–	4R	–
1F+2F	1R+2R	–	–	–
3R+5R	–	1F+2F	4R	–
3F+5F	3R+4R	–	–	–
6R+7R+8R+9R	–	1F+2F	–	–
6F+7F+8F+9F	–	–	–	–
4R	–	–	–	–

Drawing No. 1
Part No. 001
Part Name Example 1
Planner's Name Avadhesh
Date 13-2-90

FEATURE / OPERATION SPECIFICATIONS

Feature code	Finish /rough	Projected area	Basic shape	Dielect flow arrangement	Slot location	Operation type
1	R	29 14	Rectangular	Cross	Side entry	Die sinking
1	F	9.36	Rectangular	Straight	Central	Die sinking
2	R	8.04	Circular	Forward	Central	Drilling
2	F	3.30	Circular	Straight	Central	Drilling
3	R	3.20	Rectangular	Cross	Side entry	Die sinking
3	F	2.88	Rectangular	Straight	Central	Die sinking
4	R	144.00	Rectangular	Cross	Side entry	External shaping
5	R	3.20	Rectangular	Cross	Side entry	Die sinking
5	F	2.88	Rectangular	Straight	Central	Die sinking
6	R	0.95	Circular	Forward	Central	Drilling
6	F	0.59	Circular	Straight	Central	Drilling
7	R	0.95	Circular	Forward	Central	Drilling
7	F	0.59	Circular	Straight	Central	Drilling
8	R	0.95	Circular	Forward	Central	Drilling
8	F	0.59	Circular	Straight	Central	Drilling
9	R	0.95	Circular	Forward	Central	Drilling
9	F	0.59	Circular	Straight	Central	Drilling

Fig. 4.2 : Process Plan for Example Part (contd.)

COMBINED FEATURES AND MACHINING PARAMETRS

Feature code	Machined Area	Volume (cu cm)	Dielect Flow Arrangement	No of Stages	MRR (cu cm/hr)	Current (Amp)	Gap (mm)	Under Size (mm)
1R+2R	37.18	44.62	Cross	1	90.14	100.00	0.50218	1.0560
1F+2F	12.66	15.19	Straight	1	6.72	3.11	0.0243	0.0617
3R+5R	6.40	3.84	Cross	1	90.14	100.00	0.50218	1.0560
3F+5F	5.76	3.46	Straight	1	6.72	3.11	0.0243	0.0617
6R+7R+8R+9R	3.80	9.12	Cross	1	49.16	50.00	0.2036	0.5636
6F+7F+8F+9F	2.36	5.65	Straight	1	6.72	2.45	0.0188	0.0296
4R	144.00	28.80	Cross	4	147.5	200.00	0.7813	1.2090

SEQUENCED OPERATIONS

4R
1R+2R
1F+2F
3R+5R
3F+5F
6R+7R+8R+9R
6F+7F+8F+9F

ELECTRODE MATERIAL

Electrode Material	: Graphite
Polarity	: Positive

MACHINE SPECIFICATIONS

Machine Code	: MC1
Current (Amp)	: 300.000
Maximum permissible area (sq cm)	: 50.000
Type of Power Supply	: RC-type

DIELECTRIC PROPERTIES

Dielectric	: EDM Fluid PED 4549
Discharge (lt/sec)	: 1.3
Velocity (m/sec)	: 6.0
Pressure (atm)	: 1.0

MACHINING PARAMETERS

Voltage (Volt)	: 67.131
Capitance (µF)	: 42.836
Arc duration (µ sec)	: 4.847
Total Cycle Time (µ sec)	: 9.092
Frequency in kHz	: 98.891
Machining Time	: 4 hrs and 33 min

Fig. 4.2 : Process plan for the Example Part

CHAPTER V

CONCLUSIONS

The present chapter gives the summary of the present work and scope of future work in this field.

5.1 CONCLUSIONS

A computer aided process planning system for electric discharge machining process has been designed and implemented. The programming package comprises of interactive modules which decomposes the various tasks and makes the generative process planning achievable. An interactive system is developed since most of the data necessary to develop a fully automated system was not available.

The modules of the system carry out all the major functions of a process planning system. The system is capable of generating process parameters that approximate the actual cutting process to closest degree. Realistic assumptions have been made at appropriate places. It is however user's responsibility to select and input correct data and take important manufacturing decisions. This will help to reduce any inconsistencies that may arise in the course of planning.

5.2 SCOPE FOR FUTURE WORK

Based on the literature survey this appears to be the first process planning system for electric discharge machining process, expansion and modification at every stage of process planning system are possible. However, some useful suggestions/improvements are listed as follows :

1. The system capability is limited due to non-availability of the data. The system can be expanded if more data is obtained.
2. A pattern recognition system capable of identifying machined surface can be coupled with present system. This will reduce user's interaction and also errors that may result from the faulty inputs.
3. At present feasibility of the tool designs are decided by the user. A CAD procedure which designs and checks for feasibility of such tools would be integrated with proposed system.
4. For achieving the total CAD capabilities for manufacturing organization, the proposed system needs to be integrated with CAD system of other machining and fabrication processes.
5. Integration of process planning with NC part programming is suggested.

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APPENDIX A

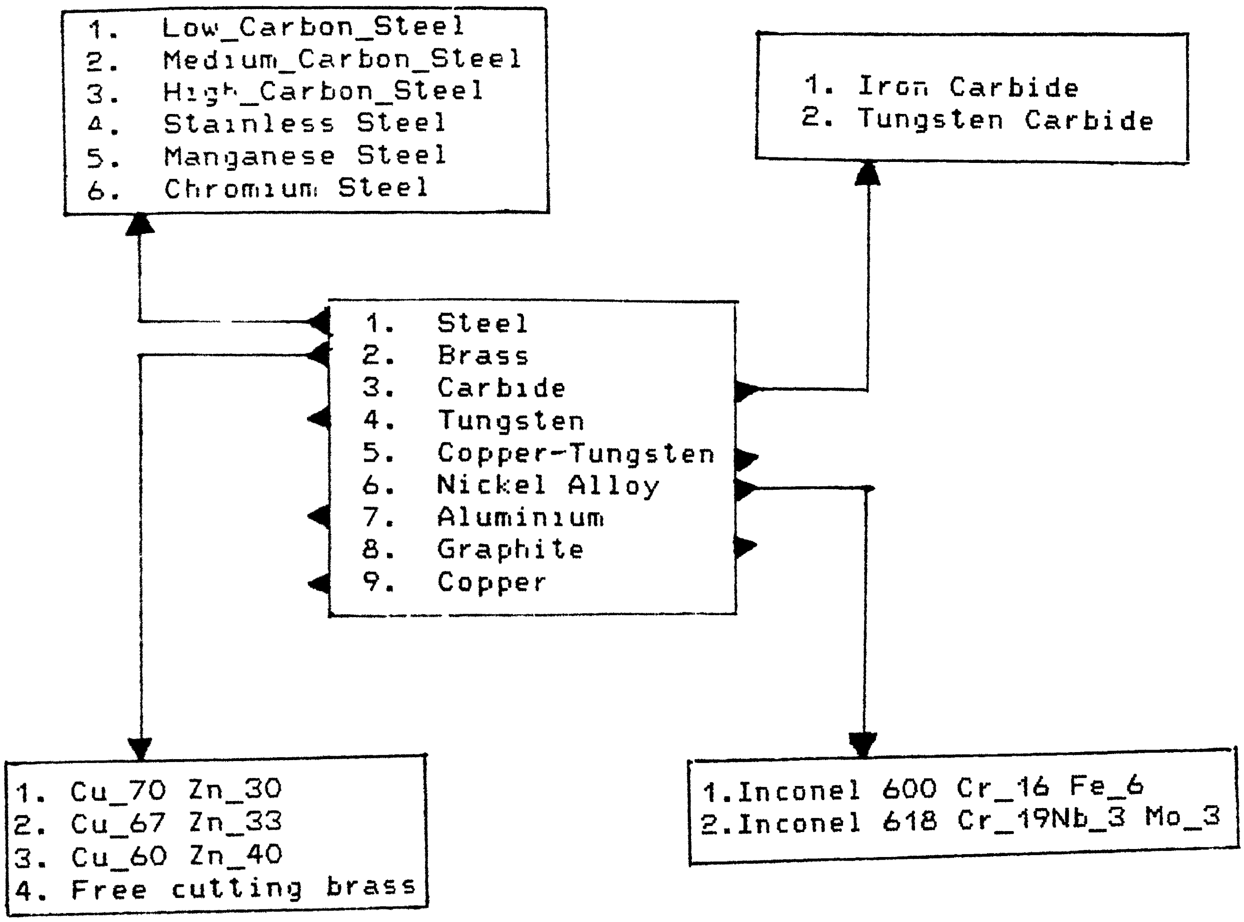

Fig. A.1 : List of Work Materials

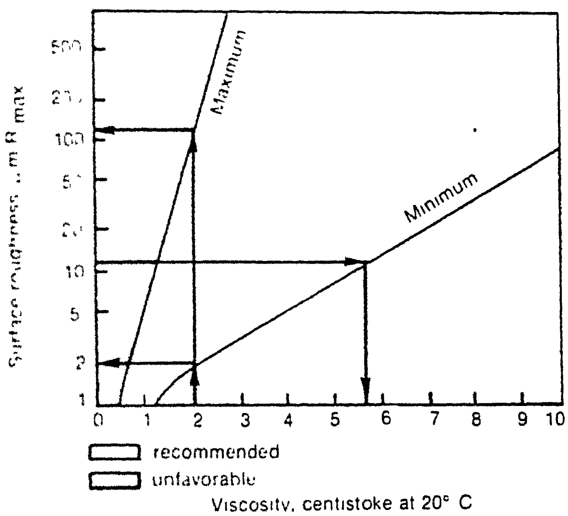

Fig. A.2 : Recommended Viscosity Range

APPENDIX B

USERS' MANUAL

The present section is to furnish the user with necessary information regarding interfacing with the system. The system is menu driven and the user has to select the desired options. To run the system the following files are necessary

CAPP.PAS	FEATURE
INPUT.PAS	COMBINE.PAS
ELECTRODE.PAS	SEQUENCE.PAS
MCTOOL.PAS	DILECT.PAS
PARAMETER.PAS	

CAPP.PAS is the main program and rest files are in units.The system can be run on MS-DOS Version 3.3. User is suggested to refer to Chapter II and Chapter III to get acquainted with basic concepts. The sequence in which things unwind are explained briefly

(i) Goto root directory i.e. C:\

(ii) Type **CAPEDM**, This loads the package and the main menu will be displayed to the user.

All the option in the menu should be performed sequentially. Any option can be selected by entering the corresponding number at appropriate place. Selection of the following option No. takes the user to :

(1) WORK INPUT screen. Enter the input values. Successful entry of data brings back the user to the main menu screen .

(2) FEATURE/OPERATION SELECTION module. Select the feature and operation to be machined.

(3) ELECTRODE SELECTION module. Select the electrode material from the displayed list.

(4) MACHINE TOOL SELECTION AND DBMS module. Select the machine tool from the displayed list. Append and edit the records if needed.

(5) FEATURE COMBINING module. Combine the features as explained in chapter 2.

(6) SEQUENCING module. Select the option for sequencing.

(7) DIELECTRIC SELECTION module. Select the dielectric from the displayed list.

(8) Display the process plan.

If the user wants to edit the program then he shall have to load TURBO 5 compiler first and then the program.

Date Slip

This book is to be returned on the date last stamped.